DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

PROBLEMS OF PROGRESS IN INDUSTRY—6

TRAINING MADE EASIER

A review of four recent studies

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PREFACE

The object of this series is to present briefly and simply the results of new research into the social, economic and technical problems of industrial progress—problems arising from automation and other advances in techniques, and problems of management and human relations. The series is commissioned and edited by the Department of Scientific and Industrial Research, which seeks only to provide a forum for responsible new thinking and to stimulate independent discussion and action, including further research. The conclusions and speculations are those of the investigators, mostly from the universities and other well-known research bodies.

This issue presents for the attention of personnel and training officers in particular, a short review of some recent research into problems of training carried out independently by teams working at one of the following:

- Birmingham University, Department of Engineering Production (E. R. F. W. Crossman and W. D. Seymour).
- British Boot, Shoe and Allied Trades Research Association, Kettering (F. G. Bailey, J. M. Hamilton, W. T. Singleton and T. F. Watson).
- National Institute of Industrial Psychology, Welbeck Street, London (Isabel J. Blain and D. C. S. Williams).
- Oxford University, Institute of Experimental Psychology (J. Annett, R. Davis, C. W. Golby and H. Kay).

The studies were supported by the Department of Scientific and Industrial Research with counterpart funds derived from the U.S. Economic Aid. More detailed accounts of some of the work have already been published elsewhere, and a list of references is given on page 30. Each team has approved the short review of its work in this booklet.

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CONTENTS

Catch phrases will never cease to be popular especially when they sum up a situation neatly and forcefully. The phrase 'sitting by Nellie' has come to denote casual and unsystematic learning of a job, in which an unskilled or semi-skilled worker is expected to pick up a new task by watching and imitating an experienced worker. A survey conducted by the National Institute of Industrial Psychology for the European Productivity Agency has shown that this is all too often the only training provided by a large number of firms in this country. Of those who have made an attempt to develop training, few have got beyond the T.W.I. (Training Within Industry) Job Instruction programme. But as Mr. St. John Wilson, Chief Industrial Commissioner at the Ministry of Labour,* who was Chairman of the Committee of Enquiry on the 'Training of Supervisors', has pointed out 'this is only a foundation upon which management can build, and those who have best succeeded with T.W.I. continue to use it as a foundation upon which to build a fuller and continuous programme of training'. He regards it 'as a success for T.W.I. if a management having tried it, decides to replace it by something better, in so far as T.W.I. may have stimulated them to think about the subject on independent lines'. He also points out that successful development of systematic training need not be limited to large firms, who recruit and train a considerable number of workers each year, provided that higher management 'take the necessary consecutive interest' in training.

Although examples of successful training schemes are found in both large and small firms, industry as a whole has not shown much interest in developing systematic training methods. However, the problem has not been neglected by human scientists. Interest in human learning and in the nature of industrial skills has fostered a number of recent research studies. The four studies, reviewed in this booklet (see Preface) are particularly relevant to the problems of training for manual operations, and although they provide no ready-made techniques for immediate use, it is

* In his Introductory Address at the Symposium on Training held by the Ergonomics Research Society, April 1958, and published in *Ergonomics*, February 1959, pp. 125–132.

hoped that they will indicate the rethinking necessary before any training programme can be formulated, and stimulate management to examine critically its present training methods and see how they could be improved.

Before making any attempt to devise a training scheme every manager, whether of a large, medium-sized or small firm, should be able to answer these two basic questions:

'What do we want our trainees to learn?'

'How can we help them to learn quickly and efficiently?'

At first sight they may appear very simple questions to answer, but the findings of these four studies alone indicate the amount of information that is needed about the man and the job before this can be done.

New ideas must often be expressed in new terminology, and it is hoped that although the reader may find some of the words unfamiliar at first to him, he will readily adopt the technical terms, all of which are carefully defined.

I. WHAT DO TRAINEES HAVE TO LEARN?

The main purpose of training in industry is to help the beginner to learn his job; in order to do this, a most important first step is to find out exactly what he will have to do on the job, and how the skilled performance of an experienced operator differs from that of a beginner.

TYPES OF ACTIVITY INVOLVED IN MANUAL TASKS

Manual tasks clearly involve fast and intricate movements of the hands and, perhaps, of other body members; but besides this physical activity it is important to recognize that the trainee's use of his senses and the decisions made in his mind are also vital, if often less obvious, components of his total performance. It has been found useful to consider these three types of activity—sensory, mental and physical—separately.

Sensory activity involves the reception of information from the senses and its transmission to the brain. Apart from the five familiar senses, there is another important one, known as the

'kinaesthetic' sense, through which information is transmitted to the brain from nerve endings in the muscles, tendons and joints and whereby knowledge is given of the position and speed of movement of a limb, and of the pressure exerted by the muscles.

Mental activity involves deciding what action to take given the information received from the senses. Decisions fall roughly into two classes. There are those in which the sensory information bears a direct relationship to the subsequent action, as for example when a car driver turns the steering wheel in the direction of the corner around which he wishes to go. Such decisions may be called '*non-symbolic*'. In the other class are those in which the sensory information has to be translated in some way according to arbitrary rules which the operator has learned. For example, a morse-code operator hears a sound pattern and translates it into a letter which he writes down. These decisions may be called '*symbolic*'. This distinction is a useful one because work involving symbolic decisions is often harder to learn. For example, a trainee takes longer to learn to operate lathe controls by reference to a dial, than he does to operate them to fixed stops. But once he has learned a task involving 'symbolic' decisions he is then able to carry it out quite automatically, for example, typing or piano-playing. The 'symbolic' mode of decision is very flexible and transferable from one situation to another but this is not usually true of the non-symbolic mode.

The third type of activity is physical movement, in which the muscles respond to the orders from the brain. The motion-study analyst conventionally recognizes certain patterns of movement, such as reach, grasp, and move, as the units of most manual tasks. But the performance of any one of these elementary actions involves many muscles, which may work in a great variety of combinations. It is the precise adjustment of these muscular actions to the job in hand which makes for a skilled performance.

What changes take place in these different activities as a man becomes skilled?

STAGES IN LEARNING

1. *Learning the sequence of activities*

First the trainee learns *what* has to be done and in what order. This is usually taught by demonstration and by verbal instruction, without first going into any detail as to *how* the different

parts of the task are to be tackled. Most laboratory subjects and industrial trainees find this stage relatively easy-going.

2. *Learning the method to be used for each part of the job*

If the trainee is being taught systematically, the instructor will show him the exact pattern of movement to use at each stage, and he will practice it in parts. Otherwise, the learner will have to discover by watching an experienced worker or by trial and error how to do each part of the job successfully.

On completing these two stages the learner can do the job successfully, but probably rather slowly. The emphasis then shifts from simple success to speed, for speed is an essential part of skill in most manual operations. The following stages are concerned with finding the fastest way of performing each of the various patterns of movement already learned.

3. *Finding the right sensory channel to use for controlling each element of the pattern of movement*

Usually a learner starts by using his eyes to guide his hands, because he can easily see the position of hands and fingers in relation to the work. But once the pattern of movement is set, it is often advantageous for him to seek information through other senses, in particular kinaesthesis. A different sensory channel may provide the necessary information earlier, giving more time for decision; or vision may simply be relieved of its load, so preventing a 'bottleneck'. Thus one of the key changes in the acquisition of skill is from 'looking' to 'feeling'.

4. *Adapting the sensory channel and organizing the information from it*

To acquire the necessary information from the work an operator may need to develop especially fine discrimination in one sense, or to perceive particular kinds of pattern in the work-materials. For example, needles are inspected for straightness by rolling them under the index finger, and the beginner must learn to distinguish the feel of a crooked needle rolling eccentrically. Again, in mending fine cloth, the learner must be able to perceive the pattern of the weave before he can work effectively. Often certain elements of a job make much more stringent demands on the senses than the others do, and these usually need to be dealt with in isolation.

5. *Using information efficiently*

As experience of the task increases, much of the information coming in through the senses becomes redundant, in the sense that it conveys nothing new or nothing important. Attention is progressively withdrawn from these cues and concentrated on the genuinely useful cues, which indicate what action is needed, guide its course, give advance warning of changing conditions, or indicate success or failure of past actions. The proper connection between information and action must be found, so that correct decisions can be taken. The pattern of movement may also be changed at this stage so as to improve the collection and use of information.

6. *Integration of the parts into a whole*

Once the sensory, mental and physical components of the task have been settled, practice leads to a more consistent performance and to smoother connections between the successive elements of the job. Sensation, decision and action come to overlap each other so that, while the limbs are performing one movement, the senses and brain are preparing the next. Thus hesitations are eliminated. Where sequences of action invariably occur together, they come to be 'triggered off' as automatic units by a single signal, as when a driver, seeing the traffic light turn green, uses clutch, gear and accelerator in a smooth sequence to pull away. Attention becomes free in the final stage to deal with special difficulties, or to pursue outside interests—like the knitter who reads while she knits.

FACTORS AFFECTING SPEED OF PERFORMANCE

A major factor which affects the speed of performance is the amount of information and decision required to guide action. This may be called the '*perceptual load*' of the task and is the main factor behind the difficulty of acquiring a new skill.

The following experiment has shown that the time taken to reach a good operational speed depends more on gathering information and acting on it than upon the extent of physical activity. Six operators were each given a pencil and were asked first to move it as quickly as possible, to and fro over the surface of an 18-in. wide paper roll, mounted on a motor-driven roller. The results were a number of wavy lines with peaks about 16 in.

apart. Next, they had to move the pencil between two lines drawn about 16 in. apart on the roll. After that they had to move the pencil over a second set of lines drawn ½ in. inside the first set, but not over the outer ones. A groove 18 in. long was then fitted over the paper track and the subjects were asked to move their pencils as fast as possible, to and fro, in the groove. Finally the pencils were fitted with a light which came on when pressure was applied, and the subjects were asked to repeat all the above operations, keeping the light on.

Table I shows how the number of movements made tended to decrease as the subjects had to guide the pencil more and more accurately between the targets, especially when they also had to maintain pressure to keep the light on.

TABLE I

MOVEMENTS ACROSS PAPER ROLL

Conditions	*Average number of moves*
Freehand	23
In groove	22
Between double lines	12
Between single lines	11
Pencil light in groove	7
Pencil light maintained freehand	6
Pencil light between double lines	5

The components of perceptual load

Just as the pattern of movements can be divided into distinct elements, such as 'grasp' or 'turn', so it is also useful to draw distinctions between the kinds of sensory and perceptual activity that make up a skilled worker's performance. Since the function of this activity is to guide and control the operator's movements, each kind of activity is connected with a particular action. For example, consider the 'reach' movement used in picking up a small item, say a nail, from among several others: the operator first looks down and finds the nail; then his hand moves towards it, slows down and stops as his fingertips come to rest on it ready for grasping; the feel in his fingertips tells him that the 'reach' movement has succeeded. Thus, three distinct components can be recognized:

Planning—taking in information, deciding and preparing for an action *before* it begins.

Control—guiding the action *while* it is going on.

Checking—ensuring that the desired result of an action has been achieved *after* it has ended.

Two other components may be involved when the signal for starting or stopping an action comes from the work or surroundings:

Initiation—triggering off an action when a given signal arrives.

Termination—stopping an action when a given signal arrives.

Each of these items requires information from one or more of the sensory channels. In the example given Planning and Control use vision and Check uses touch. The other senses—hearing and kinaesthesis—are used in different circumstances.

Also, Planning and Checking may sometimes need information remembered from an earlier stage of the job. This kind of memory when information is held in mind for a short time only, is called 'short-term memory', as distinct from the more permanent 'long-term memory'. In working from a drawing, for example, the toolmaker holds dimensions in short-term memory in order to check the correctness of his adjustments.

It is characteristic of skilled performance that these perceptual elements are carried on at the same time as the actual movements are being made, and do not hinder them. But the unskilled

worker will stop to attend to them and will be seen to hesitate, or move slowly. Indeed this is the chief visible difference between the novice and the expert.

In order to help the learner gain skill in a task, it is necessary to know what factors make the performance of these perceptual components of work easy or difficult, in the way that changes in weight carried and distance moved affect physical work.

DIFFICULTIES IN GAINING SPEED

The speed with which the various perceptual elements mentioned above can be carried out is an important consideration for the development of skill. There are three principal types of difficulty which slow them down.

1. *Discrimination:* difficulties of identifying the signals which the work presents.
2. *Choice:* difficulties of deciding between different courses of action.
3. *Control:* difficulties in the accurate guidance of movement.

1. *Discrimination.* If an operator, in order to plan, control or check his actions, has to recognize objects, or signals coming from the work, he will do so more easily and quickly if the differences between them are large, and he will find it more difficult if they are small. Experiments have shown that the ease of such discrimination depends not so much on the actual size of the difference as on its ratio. For example, in one experiment subjects were given cards, each marked with a line of one or two lengths, and asked to sort the cards into two packs according to the length of line on each. Sorting took the same time, regardless of the actual lengths of lines, provided that the ratio between the two lengths was constant. When the ratio was large (say 1:2) subjects sorted the cards quickly and easily, but when it was small (say, 3:4 or 4:5) they were slower. When the ratio was further reduced they found the task impossible. Similar difficulty was found in a study of biscuit-packing. The packer had to pick up a row of 30 biscuits to fit a tin. She was unable consistently to pick up the right number, and often had to add or take away up to 3 biscuits.

2. *Choice.* Even when the operator has recognized the correct signal, he often has to choose between several possible actions, and this takes time. A well-known test of the time taken to make a

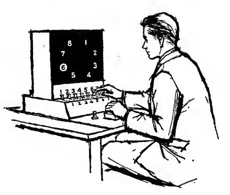
choice is the simple reaction-time in which the subject is asked to press a key as soon as a light flashes, or a buzzer sounds. He takes 0·2 seconds to respond to a light, and 0·15 seconds to a sound. Simple reaction time is, however, of little importance in skilled tasks, such as typing, where the choice is more complicated. In a laboratory study of this kind of choice, the subject was required to sort a pack of playing cards into reds and blacks, four suits, numbers and so on. The time taken was found to be proportional

to the logarithm of the number of alternatives. Thus, sorting cards into 2, 4, 8 or 16 heaps took approximately 0·2, 0·4, 0·6, 0·8 seconds respectively for each decision—together with a fixed time for movement.

The distinction between symbolic and non-symbolic decisions has been made earlier in this booklet. The times taken for these two types of decision were compared in an experiment in which the subject had to press one of a row of eight buttons when one of eight lights came on. When the task was used to measure time taken to make a symbolic decision, the lights were displayed on a screen at a short distance from the keys and showed as a circle of illuminated numbers corresponding to the numbers on the keys. When the task was used to measure time for non-symbolic choice, the lights were arranged in a row directly above the row of buttons, with the numbers on the lights corresponding to those of the

keys beneath each. The number of buttons used, and therefore the amount of choice, was varied from 2 to 8. As the number of alternatives increased, subjects experienced greater difficulty in making 'symbolic' decisions than non-symbolic ones, taking from four to five times as long over each choice.

Many industrial examples from inspection work, selective assembly, sorting tasks, to typesetting and clerical work, could be given to make this same point.



3. *Control.* Once the necessary action is decided, it usually has to be performed with some accuracy, which involves guidance and takes time. It is easy to see this factor at work in threading a needle, where the thread has to be brought into alignment with the eye of the needle. But it is not, perhaps, so obvious that the speed of most movements is determined by the 'hand-eye-brain-hand' mechanism rather than by muscular factors. The most important characteristic affecting the speed of an action is the accuracy with which the end point of movement needs to be defined. Here again it is the ratio that counts—the ratio of the accuracy to the extent of the movement determines its speed. A simple experiment shows this. A subject was asked to dot alternately between two pairs of lines each spaced $\frac{1}{8}$ in. apart, and with a distance of 10 in. between the pairs. Free movement over the distance of 10 in. took about 0·15 seconds, while the time taken to dot between the

lines was 0·5 seconds for each dot. Dotting time was found to increase as the space between the lines in each pair was narrowed or as the distance between the pairs widened. If the 'target' is not in a fixed position, or if it is not visible, the difficulty of controlling movement is also increased.

A METHOD OF ANALYSING AN INDUSTRIAL JOB

It may be argued that this type of analysis is all very well for a research worker who can, so to speak, dissect one task and examine it under a microscope, but how is the busy man in industry who is responsible for his firm's entire training policy, to cope with the problem of analysing a large number of different jobs?

As part of one of the research studies a new analysis chart—the 'Sensorimotor Process Chart'—has been designed and developed for use in industry. With its help, the sensory and perceptual components of manual operations can be recorded and studied in relation to the pattern of movements which they guide and control. The chart has been developed from the 'Two-handed Operator Process Chart' used in motion study, and like it has columns for the elements of movement, such as Reach (R) and Grasp (G), carried out by each hand, including important measurements of length travelled and weight carried. Alongside these columns, there are others for the tactual and kinaesthetic sensations coming from the operator's hands. Between these two sets of columns there are three more for the so-called 'central processes'—vision, memory and thought or decision. The column for vision is further divided to record the points on which the eyes fix during the job. A column may also be added for hearing.

Entries are made in the tactual, kinaesthetic, vision, memory or decision columns, whenever a movement is planned, guided, checked, started or stopped through one of these means. Accordingly five new symbols have been devised for use with the chart (see page 17). Each symbol represents the occurrence of a perceptual element, and can be connected by a thin line with the movement it governs.

When using this chart, the observer should first carefully record the pattern of movements. Then, proceeding down the list of elements of movement, he should discover by observation, by asking the skilled operator or by attempting the job himself, the manner of planning, controlling and checking each of the recorded elements.

He will find that many of the movements are automatic or easy, and need little or no perceptual help. In order to discover the ones that need more help, he should ask the following questions about each element of movement:

1. Does its objective change from occasion to occasion? If it does, *Planning* will be needed to redirect it on each occasion.
2. Must a given accuracy be attained, or does the target alter its position during the motion? If the answer to each question is 'yes', *Control* will be required.
3. Is it at all likely to go wrong? If it is, *Check* will be required.
4. Is it started or stopped in response to any outside signal? If it is, *Initiate* or *Terminate* will be required.

Next, the observer must find out which sensory channel is used, and whether or not short-term memory or decision comes into play, and make an appropriate entry in the chart.

By studying an operation in this way, the observer focuses his attention on each of its sections in turn, and builds up in his mind a clear picture of its demands. He can estimate the relative difficulty of the whole job and its sub-sections, and the amount of improvement that is likely with practice, by noting the amount of perceptual activity. He will also be able to detect the perceptual 'bottlenecks' and thus improve the method by eliminating them or rearranging them to spread the perceptual load more evenly. In relation to training, he will be able to devise exercises and instruction to enable the trainee to build up an effective relationship between perception and movement more quickly.

The task of soldering provides an illustration of the sensori-motor process chart and its use (see page 17). To make a joint the operator applies her iron with the right hand and flux-cored solder with the left, melts and applies enough solder, then waits for the joint to cool to see if the joint is 'dry', or not. A film study of this operation showed that the visual checking accounted for about one quarter of the total time, and observations indicated that the feeding of the solder, using kinaesthetic and visual control, was a difficult operation. The visual sense was clearly the 'bottleneck' in this operation. Improvement was possible by simplifying the method of feeding solder and so eliminating the need

for visually checking the joint. Training could concentrate on the positioning and controlling actions in heating the joint, and on how to recognize the quality of the joint as early as possible.

II. HOW CAN TRAINEES BE HELPED TO LEARN?

IMPROVING EXISTING WORK METHODS

One way of helping the trainee to learn a new task quickly is to make the job itself easier. A careful analysis will indicate the most difficult parts of a task and it may be possible to make some relatively slight alterations in the layout, the method or even the sequence of movements, and so make it easier both to learn and to carry out continuously. Here again the sensorimotor process chart can help.

The difficulty of a task can often be assessed quickly from the number of entries in the symbolic decision column of the sensorimotor process chart. A decision should be allowed to remain only

Left hand	K	T	Mot	Brain: Mem	Brain: Dec	Brain: Vis 1	Brain: Vis 2	Right hand: Mot	T	K	Right hand	Notes
Holding iron											Holding solder	Solder one joint
			—					—			—	Find next joint on list
To joint			M 6 in.					—			—	
Tip on wire			P					M 4 in.			To joint	
H			H					P			Solder on tip	
H			H					H			H	Wait for solder to melt then feed more on
H								M 1 in.			Feed solder	Avoid kinking and slipping. Stop when sufficient
Remove iron			M 1 in.					M 1 in.			Remove solder	Watch joint till surface changes from bright to filmy.
Await cooling			—								—	Observe junction with wire. Decide whether good joint
			—								—	and either repeat or look for next joint.

Operation: sub-chassis soldering

Symbols used in Sensorimotor Process Chart

Perceptual activities

- Plan ∨
- Control
- Check ∧
- Initiate O
- Stop ●

Movement

- Move M
- Position P
- Hold H

Sensorimotor Process Chart

if it makes a direct contribution to the work; otherwise it is evidence of a wrong method. As it has been found that symbolic decisions take the operator much longer than non-symbolic, a change of method may help the operator to use non-symbolic decisions, with a consequent speeding up. Work will always be made less difficult by a reduction in the amount of decision making.

The sensory, mental and physical activities should be arranged so that action is not delayed until the decision is made, nor should the decision be delayed for lack of information. For example, where a trainee uses his eyes to check machining, and in the same cycle has to grasp an object, if the object is always in the same position, he will learn to grasp it and move it into position for the next operation, mainly by feel (kinaesthesis). Similarly, on an assembly task the operator learns to pick up and move material into place at the same instant as his eyes check his previous work before he lays it aside.

The necessity for an operator to rely on his memory in order to provide continuity may often be eliminated by changing the sequence of operation, or by modifying the instruments so that information is displayed until he has carried out the action or cancelled the display.

Other improvements depend on:

1. Eliminating unnecessary variation from the job, for example by the prepositioning of tools and orderly arrangement of parts and materials.
2. Rearranging the motion cycle so that the elements fit more effectively together. This sometimes means departing from the symmetrical, two-handed movements recommended by some motion-study experts. If it is found from analysis that the eyes must supervise the work of both hands, and that the work cannot be done kinaesthetically even by a skilled operator, a quicker and easier method may be developed if the eyes supervise each hand in turn and if the movement of one hand is timed to follow that of the other, instead of both moving together.
3. Providing clearer and easily understood signals, by modifying instruments, tools or work layout.
4. Allowing greater freedom at the end point of movement so as to reduce the accuracy demanded and,

therefore, the difficulty involved in the work of the senses and in making decisions. This can be done by providing lead-ins for assembly, funnels for containers and similar devices.

IMPROVING METHODS OF TRAINING

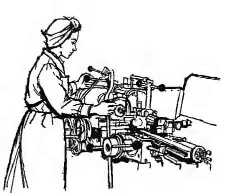
The problem of how to speed up and improve the efficiency of learning has been tackled from one or more angles in the four research studies. Although this booklet is restricted to their findings, it must be emphasized that they do not represent anything like the complete or final picture nor do they provide training rules to be applied generally. Each training situation has its own features, and must be studied individually. No two training problems are identical. However, the findings illustrate how research can help industry to achieve efficiency in training.

'Whole' v. 'part' learning

Three methods of training have been investigated in one experiment.

1. The 'whole' method, where a complete task is always practised from beginning to end.
2. The 'progressive part' method, where the learner practises one part of a task until he is able to do it at the target speed, which is the speed taken by the average experienced worker. When any two successive parts can be done separately in the target time they are practised jointly until the required speed is achieved. Then a third part is added and so on, until the complete job has been learnt.
3. The 'isolation' method, where the learner is trained on part of a task until he reaches the target speed in each part separately. Then the parts are combined.

In this experiment the three methods were tested on three groups of young workers, aged between 15½ and 18 years, who were individually taught to operate a capstan lathe in five successive days, each group by a different method. Those in the group learning by the *whole* method were shown the operation at the beginning of the first half-hour session, and were given the target time of 45 seconds for the whole cycle. They were asked to repeat the movements correctly and as quickly as possible. At intervals



they were told their times for the operation. At the end of the fifth individual session a five-minute test run was given.

Those in the group learning by the *isolation* method practised first on the turret until they could operate it correctly in target time, then on the cross slide and then on the whole job. They also had a test run at the end of the fifth training session.

Those in the group learning by the *progressive* part method first practised loading and unloading, then the cross slide operation, then the turret operation, reaching target time on each one before going on to the next. They then practised loading, switching on and cross slide together, and after reaching target time they tried the cross slide and turret together. Finally, at the end of the fifth session they were tested on the complete operation.

When the young workers were tested at the end of the fifth day, those who were trained by the isolation and progressive part methods, made a greater number of clear runs and fewer errors than those who learnt by the whole method. (See Table II.)

TABLE II

COMPARISON OF THREE TRAINING METHODS

Method of learning	*Clear runs*	*Turret Errors*	*Cross slide Errors*
'Whole'	56	18	13
'Isolation'	96	13	5
'Progressive part'	103	4	4

A non-verbal intelligence test was given to the subjects, but there was no significant link between speed of gaining skill and intelligence. Thus, the method of learning seems more important than individual intelligence in this instance.

Fitting the training method to the job

It is not possible to say simply which method is superior for a particular kind of job. Some kinds of task seem to call for the isolation method, for example, work involving a complex sequence of interdependent manual operations looks impossible to a learner. If he makes one mistake, the whole sequence goes wrong and, unless he knows how to remedy his mistakes at each stage, he is likely to make more mistakes in trying to correct himself.

Sometimes learners have to be trained on a machine or a conveyor which sets the pace of work and even the sequence of actions. In such cases it is possible to approach the isolation method in another way. A complicated job may be reduced to its simplest form, taught in this form, and the complications reintroduced gradually as each stage is mastered.

For example, a training scheme for weavers of chenille carpets has been devised by a group of research workers. In the weaving process the loom stops after every fifth shot of chenille weft. The operator takes the chenille thread in one hand and twists it so that the tufts are towards her. Then, with her other hand, she combs the tufts into position in the pattern being woven. As successive chenille threads must be combed in opposite directions, the operator must be able to do this twisting and combing as well with her left hand as she does with her right. In addition she has to learn the usual weaving operations, such as replenishing shuttles, mending warp and weft breaks, and so on.

A detailed analysis of the various parts of the job was made and a formal training programme drawn up, with a definite task set for each part of the day. It was noted that skilled workers were able to twist the thread into place and comb the tufts into position with long swift strokes, but trainees usually 'fiddled' with the threads to twist the chenille tufts uppermost, and made small pecking movements with the comb.

The twisting and combing were therefore taught separately from the weaving operations. The trainees were encouraged from the beginning to use only the same movements as the skilled

workers. Special practice was given to the non-dominant hand to ensure that it became as skilled as the other hand at setting the thread and combing the tufts.

At first only plain or mottled carpets were used. Later trainees were introduced to patterns regarded as easy by the skilled weavers, in order to build up the skill of combing the tufts into exact position in the patterns.

Simple explanations of the working of the loom, using a model, and of the sequence of operations were included in the training programme.

Since the introduction of this training scheme the average time for a trainee to reach piece-work rates has been from four to six weeks, compared with about nineteen under the 'sitting by Nellie' method.

Learning by trial v. *learning by instruction*

Two training procedures have been contrasted in another laboratory experiment. In one, the 'activity' method, a learner tries to learn a task by performing it up to the point where he fails. He is then given the necessary information to correct his mistakes, and allowed to go on until the next breakdown. In the other, the 'non-participation' method, the learner is told exactly what he must do.

In this experiment, the subjects had to learn a simple 'maze' task, in which they had to take either the right or left path at a series of junctions occurring every two seconds. Under the 'activity' method, the trainee had to decide in which direction to move and to discover later whether he had been correct. Under the 'non-participation' method, the trainee was shown which path to take before he moved. Under both methods, the final task was to learn to make the series of left or right responses when no indication was given at the junctions.

The results were surprisingly clear cut. The group learning by the activity method took, on the average, twice as many trials as the other group to learn the task. The advantage of the non-participation method seemed to be that the trainees did not have to make a series of decisions which might or might not prove to be correct, but had only to learn a constant series of signals, as presented by the display. They learnt more efficiently than the activity group, for whom the series was broken up by a number

of signals from their own responses, some of which had to be discarded.

The motor responses in this task were simple and the sequence of the moves was the main item to be learned; but the task was rigidly paced, allowing only a short time interval at each junction point. Paced conditions of work are increasingly common in industry, and this experiment emphasizes the need to reduce a learner's uncertainty about what he has to do. Controlled time-work relationships do not always allow the operator enough latitude to check and, if necessary, adjust his responses.

AIDS TO LEARNING

Knowledge of results

Difficulty in learning some jobs arises from the identification of 'sensory' cues which will guide the responses satisfactorily. Training devices may be used to help the learner to do this.

Where the learner has to apply a specific pressure as part of a skilled task, he may have to learn the 'feel' of the correct pressure. A light or buzzer which signals when the correct pressure is achieved may help him to identify the 'feeling' which will guide his response correctly. Knowledge of results given by such aids can only be considered effective if it accelerates the learning of the 'natural' response. Unless they are used wisely and sparingly, such aids to initial learning may delay achievement on the normal task.

An experiment was designed to discover how to give learners the requisite extra 'cues' so that they gained the desired skill without becoming dependent upon them. Trainees had to exert pressure on a plunge-type handle, hold it for three seconds and return to rest, repeating the operation at ½-second intervals. They were told that they must learn to exert the target pressure in the first 50 trials, during which they would be given indications of their success. Then they were to repeat the job for another 70 trials without any indication of success.

Trainees in one group were able to see an illuminated scale on which the correct pressure was marked with a red line. They were asked to reach the correct pressure at each attempt, and were allowed to correct over-shooting. Another group pressed the handle until a neon lamp came on showing that the correct pressure had been reached. As the lamp only flashed at the target point they

were unable to tell how far they were from achieving the correct pressure. A third group had the scale reading told to them as they pressed. They knew the target was '20' in a scale of '40'. This group gained plenty of experience in exerting wrong pressures: and even when they got it right there was a slight delay before they knew, i.e. before it was read out to them. The fourth group tried to press to target pressure; they were then shown the scale and could judge how far off they were at each attempt.

During the learning trials the first and second groups gave accurate pressures at each attempt. The third and fourth were able to make only a few correct attempts towards the end of the trials. When in later trials no indication of success or failure was given, accuracy fell off markedly and more rapidly—misjudgment of pressure being three times greater—in the first two groups, whose learning had been aided by a visible scale or light, than in the other groups.

When knowledge of results is given *after* the response has been made, correct action can only result from the use of information always present in the task. Once this guidance has been learned additional cues become superfluous and the learner settles down to a consistent performance.

In another study, the provision of scales has helped learners to control the speed of a sewing machine. As the learner presses the

treadle and the movement of the needle quickens, a scale at the side of the machine shows the number of stitches a minute at that pressure. The trainee must watch the work under the needle, as well as the scale, and this division of attention probably means that the scale reading does not become quite as much of a 'crutch' as it did in the pressure experiment, where there was no other information for the eyes. In the present instance the trainee finds the scale a nuisance as well as a help and the sooner she can do without it the more comfortably she can concentrate on machining the work under the needle. Information from her feet, from the sound of the machine in her ears, and the sight of the material passing beneath the needle will finally be better guides to control of the speed.

Knowledge of quality

Knowledge of results may be given in terms of quality as well as of quantity of work, thus enabling a novice to learn to judge when his work is above or below standard.

Left on his own, a trainee may set himself standards which are unattainable at the current stage of his learning, and may develop an unjustified sense of failure that tempts him to deviate from the recommended methods in an effort to achieve better output.

Reasonable and normally attainable targets are needed at each stage of learning to give the trainee real knowledge of his actual progress. Investigation suggests that learners may be keener to produce correct work than quick work, in spite of the fact that they may be aiming at piece-rate earnings. It may be necessary to settle the degree of accuracy required and also the point at which to begin encouraging speed. The presence of faults may then be freely acknowledged by both instructor and learner; while if the learner can be shown that he is improving step by step, he may be helped, without destroying his standards of quality, to recognize that he is making appropriate progress and that he need not feel his efforts are fruitless or wrongly directed. He must be given to understand that only by acquiring correct methods such as are used by a skilled worker will he become consistent in quality as well as speed.

It was found worthwhile, for example, in the machining of singlet armholes, to insist on one such method from the start—the trainees practised a long continuous movement on waste

material cut to correct shape, stitching round the whole armhole without stopping the machine to rectify the faulty alignment of stitches which occurred, as would be expected, in the early attempts. Attention was thus focused on the prescribed *method* of working, and in the process of acquiring this method faults gradually, almost automatically, disappeared.

A learner can be helped by good instruction to identify the 'feel' of movements that produce the right results, and to discern differences in 'feel' which are in fact early signs of trouble; if he gets this help while, at the same time, developing finer muscular control with which he adjusts his movements to meet the changing situation, his quality should become more consistent as his speed of work increases. Acquisition of the most efficient method and ability to notice the first signs of trouble are not left to chance in a systematic training scheme; they are its aim.

Another facet of the learning experience which affects speed is the necessity in many jobs of ascertaining that the actions have produced the right result—'not too little, not too much, but just right'. It is relatively easy to recognize very bad results, but often much time is spent looking at results whose quality is about average, to decide what is just acceptable and what will fail to pass inspection. No worker can be a high producer if he hesitates in making this distinction. Crucial differences can, however, be pointed out and practice can be given in recognizing them.

Competition

Knowledge of results may lead to competition between individuals or groups. In one experimental study of the training of maintenance electricians, competition between groups was introduced in this way. Speed of work was deliberately discouraged by the employing organization, as quality was considered all important. The quality of the learners' practice exercises was carefully marked, but by a system which in fact left little room for improvement over normal achievement. A course of instruction was given by the same people to a series of eight groups of learners. The trainees in each group sat at benches arranged in two rows. On four of the courses, a chart was put up at the end of each row, which was visible to all the trainees in the class. This gave the total scores, in terms of quality and quantity, of the trainees in that row, at the end of each morning and afternoon. The scores of

individual trainees were not given. On the other four courses no scores were displayed. The amount (but not the quality) of the work done by the 'competing' groups was significantly greater than in the 'control' groups in spite of the official emphasis on quality at the expense of speed. It appeared that this way of presenting information about progress had definitely helped to stimulate interest in the work.

III. PROBLEMS OF APPLICATION

The results of these studies indicate how much is involved in setting up a systematic training scheme. It is necessary first to study a job by dividing the work of an experienced operator into sensory, mental and physical activities. Then, by comparing his performance with that of a trainee, it is possible to pick out for special training those parts of the job on which the experienced worker achieves a greater speed. Special training may be given in the three types of activity: in how to select the appropriate sensory cues, and to ignore all irrelevant information; in how to take quick decisions, based on the information from the senses, as to what action is needed; or in how to carry out the physical response. The details of how to give training depend on the complexity of the job and need to be worked out separately for each job. However, certain general techniques, such as providing knowledge of results, may be valuable in encouraging the trainee to learn.

These results stress the importance of making careful plans for training. It is impossible to rush into a training scheme, and to hope to hit on a good one by chance. This booklet will have fulfilled its aim if it causes managers to re-examine their own training methods and encourages improvement where necessary. Managers who have got by with the 'sitting by Nellie' type of training, may wonder whether all the trouble of setting up a systematic training scheme is really worth while. It is impossible to point to immediate financial benefit as no direct expenditure is involved in the informal method. There are, however, other ways of estimating the value of training schemes. For example, as a result of the training scheme set up in the carpet factory (page 21)

trainees achieved piece-rates in 6–8 weeks, compared to 16 weeks under the old method. Wages were made up to the basic rate, so that this reduction in the time taken to reach piece-rate standards meant a considerable saving. There was some evidence to suggest that if a trainee reached these standards sooner, he would be less likely to leave than otherwise, thus labour turnover rates would be lower. It is also worth estimating the cost of *not* training, in terms of the scrap, wastage of raw materials, loss of orders through delays in production, wasteful use of overheads, etc., and balancing these against the relatively small expense incurred in setting up systematic training.

Once a firm has decided that there is room for improvement in its training methods, then is the time to seek expert advice. When a new technical device is being introduced, the firm depends on expert advice in selecting the one most suited to its needs. Equally important is expert guidance in drawing up systematic training programmes. These theories of training have not yet been developed to the stage where they can be handed over directly to ordinary industrial staff. In fact the design and introduction of training schemes should be supervised by a specialist with psychological training, as a full-time or part-time member of the staff. Firms that cannot afford to do this can always turn for help to their trade associations, which may form a central pool of equipment and personnel, or train learners in a separate school or plan a scheme and train supervisors for a member firm. Such a service is provided by Satra (the British Boot, Shoe and Allied Trades Research Association). Satra has set up an experimental training centre to improve methods of training by introducing techniques developed from their detailed studies of skilled operatives, and incorporating modifications to equipment design recommended as a further result of these studies. The analyses of the trainees' performance on the course and subsequently in the factory provide information for evaluating new training methods. As a result of experience in the training centre, Satra has developed a general system of training and spread it through the industry by organizing courses for instructresses. In addition to the large firms who run their own training centres, small firms can benefit by sending their trainees to local technical colleges. All the colleges in the shoe-making areas have teachers trained in the Satra methods.

The final step in setting up systematic training is to select a competent supervisor for the training school, as this will always be the most important feature of any training system, for even the best scheme depends for its success on the people whose job it is to apply it.

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Readers wanting further information about systematic training, are invited to write to the Department of Scientific and Industrial Research's Technical Enquiries Section, which will put firms in touch with university departments specializing in industrial and applied psychology, or with technical institutions such as the National Institute of Industrial Psychology.

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